

Analysis for MRI of Brain Volume Changes in Dementia

1. Introduction:

This study aims to examine the significant cognitive impairments and disruptions to daily living activities caused by dementia, as evidenced by structural changes in the brain observable through Magnetic Resonance Imaging (MRI). Specifically, it will analyze MRI data to understand how dementia-related brain atrophy is reflected in changes in normalized whole brain volume (nWBV) and Atlas Scaling Factor (ASF).

We will employ the dataset 'INF2178_A4_data.csv', derived from a longitudinal MRI study of patients with and without dementia, to investigate the design within subjects and the statistical power of the study. By applying mixed-effects Analysis of Variance, this research aims to delve into the evolving relationship between the status of dementia and variations in brain volume over time. Our analysis will tackle two key research questions:

- Does the Normalized Whole Brain Volume (nWBV) change across different visits for each group (Demented, Nondemented and converted), and is there an interaction effect between visits and group status on nWBV changes?
- Does the Atlas Scaling Factor (ASF) change across different visits for each group (Demented, Nondemented and converted), and is there an interaction effect between visits and group status on ASF changes?

2. Data Cleaning:

This dataset contains a total of 16 columns and 294 rows, since we will only need 5 variables for our research questions so we can drop all the unnecessary columns. Below are the descriptions for each column:

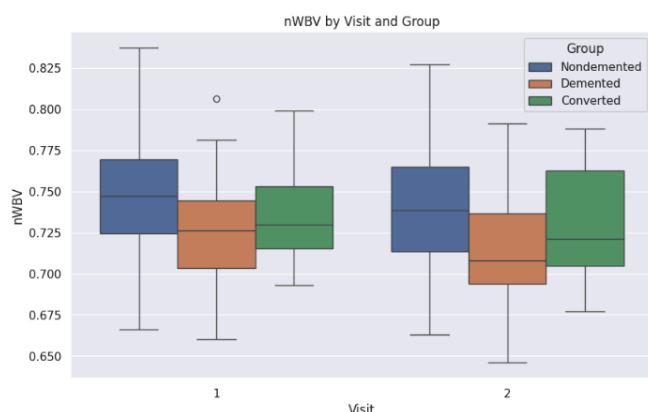
- **Subject ID:** The unique ID for each participant in the study.
- **Group:** Classification of participants according to their dementia status (demented, nondemented, or converted).
- **Visit:** The number of times a participant has visited.
- **nWBV:** Normalized Whole Brain Volume, a metric pertaining to the overall size of the brain.
- **ASF:** Atlas Scaling Factor, A factor employed in the quantification of brain volume.

3. Exploratory Data Analysis (EDA):

In our exploratory data analysis, we will get an initial review of the dataset from the summary statistics as we can see below:

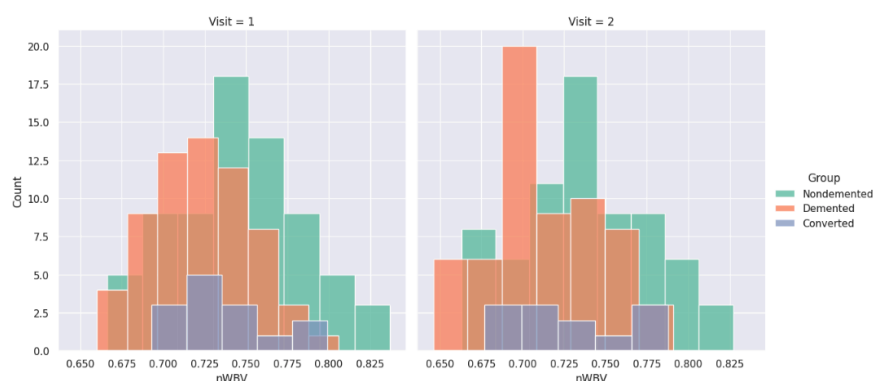
index	Visit	nWBV	ASF
count	294.0	294.0	294.0
mean	1.4898	0.7314	1.2031
std	0.5007	0.0373	0.1394
min	1.0	0.646	0.876
25%	1.0	0.703	1.1183
50%	1.0	0.732	1.201
75%	2.0	0.756	1.3028
max	2.0	0.837	1.587

Then, we can use boxplot to illustrate how the normalized whole brain volume (nWBV) distributed across multiple visits among three categories of patients.

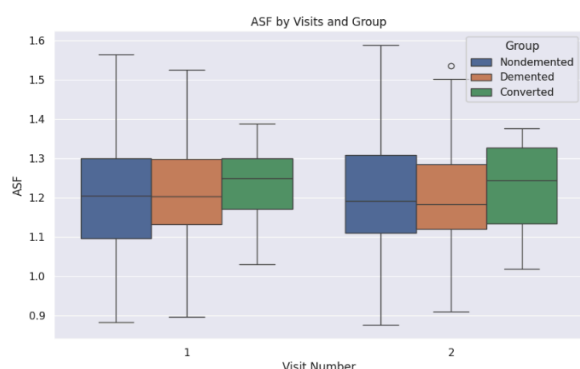


The boxplot shows nWBV for Non-demented, Demented, and Converted groups at two visits. The Non-demented group's median nWBV decreases slightly over time, while the Demented group's remains consistently lower across both visits. The Converted group starts with higher nWBV like the Non-demented but drops by the second visit, nearing the Demented group's median, suggesting disease progression.

Next, we use histogram to compare normalized whole brain volume (nWBV) across two visits for the groups.

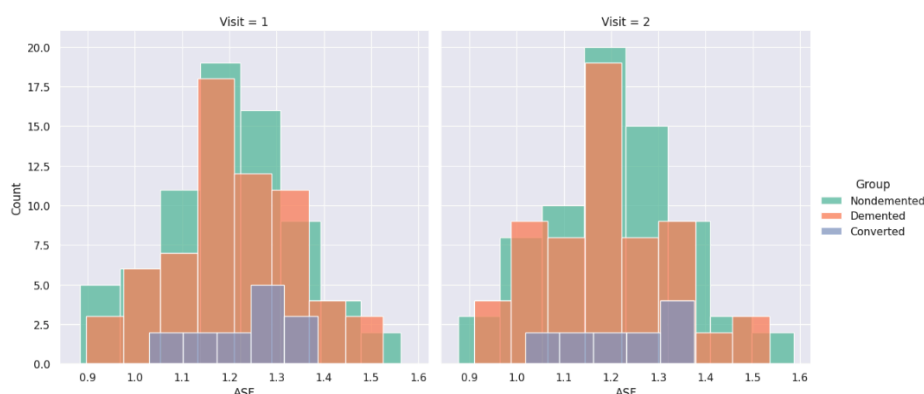


The Non-demented individuals have higher nWBV, peaking to the right, while Demented subjects show lower volumes, with the peak shifted left. Converted individuals' nWBV distributions fall between the other groups. All groups' nWBV frequencies decrease by the second visit, suggesting a general decline in brain volume over time.



The boxplot shows the Atlas Scaling Factor (ASF) across two visits for Non-demented, Demented, and Converted groups. The medians are similar across groups and visits, suggesting ASF does not vary significantly with dementia status or over time. Variability within groups is moderate, with one outlier in the Non-demented group during the first visit.

The histogram presents the distribution of Atlas Scaling Factor (ASF) for Non-demented, Demented, and Converted groups over two visits.



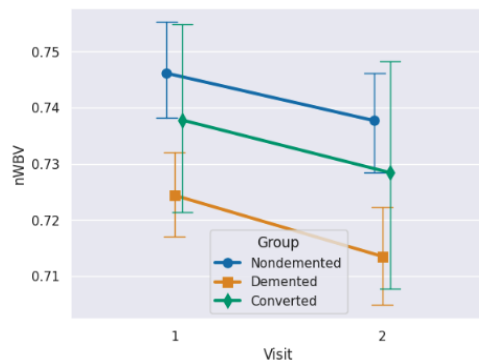
Each group shows a similar distribution pattern across both visits with no significant changes, implying stability in ASF measurements over time. The Non-demented group has a marginally higher frequency of higher ASF values, while the Demented and Converted groups have a broader distribution across the ASF range.

4. Mixed Effects ANOVA Analysis:

In this mixed-effects ANOVA analysis part, we initially focus on the point plot, which will assist us in gaining visual insights into the dynamics of both normalized whole brain volume (nWBV) and Atlas Scaling Factor (ASF) across different visits and groups. Subsequently, we will perform the mixed-effect ANOVA to statistically evaluate the main and interaction effects of group status and visit on nWBV and ASF. Lastly, we will conduct assumption checks for normality, homogeneity of variances, and sphericity to validate the ANOVA model, ensuring our analysis stands on robust statistical ground.

Research Question 1: nWBV change across visits for each group

We use point plot to analyze changes in nWBV across different visits for each group.



The point plot indicates that all groups experience a decrease in normalized whole brain volume (nWBV) between two visits. The plot suggests an interaction effect where the rate of nWBV decline might differ by group, with the Converted group showing a distinctive pattern potentially resembling the Non-demented group over time.

Now, let's look at the result from the two-way mixed-design ANOVA:

index	Source	SS	DF1	DF2	MS	F	p-unc	np2
0	Group	0.0336	2	141	0.0168	6.7121	0.002	0.0870
1	Visit	0.0065	1	141	0.0065	94.2512	2.226e-17	0.4006
2	Interaction	0.0002	2	141	0.0001	1.5335	0.2194	0.0213

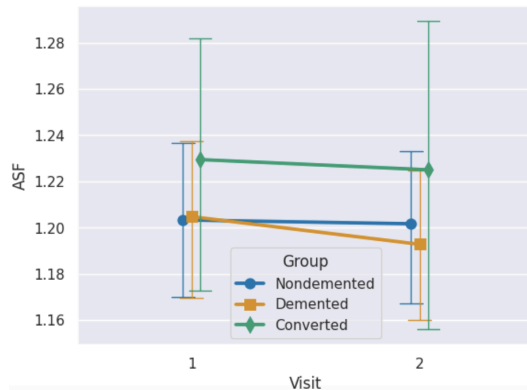
The results shows significant main effects of Group and Visit on normalized whole brain volume, with Group having a p-value of 0.002 and Visit having a p-value of less than 0.001, both associated with large F-values indicating a strong statistical finding. However, the interaction between Group and Visit is not significant ($p = 0.219$), with a lower F-value (1.534), indicating that the difference in nWBV between groups does not vary significantly from one visit to the next. This indicates that while group status and visit time individually influence nWBV, their interaction does not significantly affect it.

Lastly, we will check the assumptions:

1. Sphericity: We use Mauchly's test for sphericity, The value of 1.0 suggests that the sphericity assumption has not been violated.
2. Normality: The Shapiro-Wilk test for normality get W values close to 1 (0.9901 for Visit 1 and 0.9897 for Visit 2) and p-values (0.3721 for Visit 1 and 0.3667 for Visit 2) greater than 0.05, indicating that the nWBV data for both visits follow normal distribution.
3. Homogeneity of Variances: Levene's test reports a W value of 0.5044 with a p-value of 0.4781, which is also above 0.05, assumption of homoscedasticity is met.

Research Question 2: ASF change across visits for each group

We use point plot to analyze changes in ASF across different visits for each group.



The output plot appears to show a slight decrease in Atlas Scaling Factor (ASF) from Visit 1 to Visit 2 for the Non-demented group, which contradicts the observed increase for the Demented and Converted groups. The most notable observation is the variability in ASF for the Converted group at Visit 2, as indicated by the wide error bars. This variability suggests inconsistency in ASF measurements within this group over time.

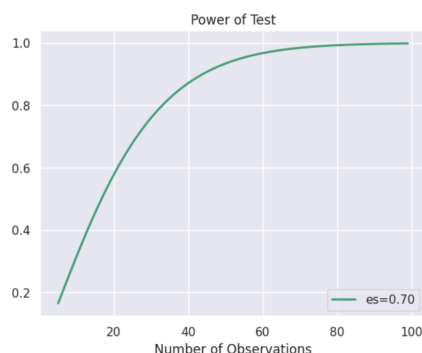
Next is the result from the two-way mixed-design ANOVA:

index	Source	SS	DF1	DF2	MS	F	p-unc	np2
0	Group	0.0184	2	141	0.0092	0.2337	0.7919	0.0033
1	Visit	0.0032	1	141	0.0032	8.7543	0.0036	0.0585
2	Interaction	0.0007	2	141	0.0004	1.0276	0.3605	0.0144

The results show that time significantly affects Atlas Scaling Factor (ASF), with visit changes being significant (p-value = 0.0036). However, group differences don't significantly impact ASF (p-value = 0.7919), and there's no meaningful interaction between group and visit (p-value = 0.3605), indicating that visit timing affects ASF, but group type and the specific combination of group and visit do not.

Assumption check: For an ANOVA on the ASF indicate that the data meets the required conditions: sphericity is assumed with a value of 1.0, the Shapiro-Wilk test confirms normal distribution of ASF at both visits with p-values well above 0.05, and Levene's test supports homogeneity of variances across groups with a p-value of 0.723468.

5. Power Plot:



Based on a power of 0.91, an effect size of 0.7, and an alpha of 0.05, the calculated sample size required per group is 45.451, which we round up to 46. The accompanying power plot demonstrates a positive correlation between the sample size and the test's power, confirming that larger samples improve the likelihood of detecting a true effect.

6. Conclusion:

In summary, the study reveals that Normalized Whole Brain Volume (nWBV) significantly differs among dementia-related groups and across time of visits, yet these two factors do not interact to affect nWBV. Conversely, Atlas Scaling Factor (ASF) changes significantly over time of visit but not between groups, and similarly exhibits no interaction effect. These insights enhance our understanding of dementia's impact on brain volume and the importance of considering time in its progression.